Claims

1   1.   A method of modifying a virtual object stored within a computer, the method comprising the

2   steps of:

3   representing a virtual object as a volumetric model;

4   converting a subset of the volumetric model into an alternative representation;

5   determining a response of the alternative representation to a stimulus; and

6   modifying the volumetric representation so as to substantially represent the response of

7   the alternative representation to the stimulus.

1   2.   The method of claim 1, wherein determining a response of the alternative representation

2   to a stimulus comprises determining a response of the alternative representation to a first

3   stimulus and further determining a response of the alternative representation to a second

4   succeeding stimulus.

3   3.   The method of claim 1, wherein modifying the volumetric representation comprises a

2   change in shape of the volumetric representation.

4   4.   The method of claim 1, wherein modifying the volumetric representation comprises

2   converting the response of the alternative representation to the stimulus into a response of the

3   volumetric representation to the stimulus.

1   5.   The method of claim 1, wherein the subset of the volumetric model is the entire

2   volumetric model.

1   6.   The method of claim 1, wherein the subset of the volumetric model is a portion of the

2   volumetric model.

1   7.   The method of claim 1, wherein the volumetric model comprises voxels.

1   8.   The method of claim 1, wherein the volumetric model comprises values spaced in a three-

2   dimensional grid.

1   9.   The method of claim 1, wherein the alternative representation comprises a surface

2   representation.

1   10.   The method of claim 1, wherein the alternative representation comprises a set-of-triangles

2   representation.

    11.   The method of claim 10, wherein the stimulus comprises a weighted displacement

2   function defined on vertices of the set-of-triangles representation.

    12.   The method of claim 1, wherein the alternative representation comprises a selected one of

2   a polygon set, a bezier surface, a b-spline surface, a procedural surface, and a NURBS

3   representation.

1   13.   The method of claim 1, wherein the alternative representation comprises an alternative

2   voxel representation.

1   14.   The method of claim 1, wherein the stimulus is a stimulus from a user using a haptic

2   interface.

1   15.   The method of claim 14, wherein the haptic interface is a force feedback interface.

1   16.   The method of claim 14, wherein the haptic interface has at least three degrees of force

2   feedback.

1   17.   The method of claim 1, further comprising the step of displaying the virtual object on a

2   computer display.

1   18.   The method of claim 1, wherein the volumetric representation and the alternative

2   representation comprise representations having different numbers of dimensions.

1   19.   The method of claim 1, wherein the applied stimulus comprises at least one of a

2   displacement function, a smoothing function, a warping function, a volumetric interference, an

3   areal interference, a result of a simulation, a control point modification, a data re-fitting, and a

4   force.

20.   The method of claim 1, wherein the applied stimulus is applied to the object in real time.

1   21.   The method of claim 1, further comprising the steps of:

2   transforming the alternative representation into a third representation;

3   modifying the third representation in response to an applied stimulus; and

4   transforming the modified third representation to a modified volumetric representation.

1   22.   The method of claim 21, wherein transforming the modified third representation to the

2   modified volumetric representation comprises generating an intermediate modified

3   representation.

1   23.   The method of claim 1, wherein the stimulus comprises a user motion in the at least

2   three-dimensional space.

1   24.   The method of claim 1, further comprising applying a feedback force to a user, the

2   feedback force being generally consistent with a geometric shape of a modified virtual object.

1   25.   A method of modifying a volumetric representation of an object, the method comprising

2   the steps of:

3   transforming at least a portion of the volumetric representation into a polygonal set

4   representation;

5   modifying the polygonal set representation; and

6   modifying the volumetric representation to substantially represent the modification made

7   to the polygonal set representation.

1   26.   The method of claim 25, wherein the modification comprises a selected one of a

2 displacement function, a smoothing function, a warping function, a volumetric interference, an

3 areal interference, a result of a simulation, a control point modification, a data re-fitting, and a

4 force.

1   27.   A method of modifying a volumetric representation of an object, the method comprising

2 the steps of:

3   transforming at least a portion of the volumetric representation into a surface-based

4   representation;

5   modifying the surface-based representation; and

6   modifying the volumetric representation to substantially represent the modification made

7   to the surface based representation.

1   28.   A system for modifying a virtual object stored within a computer, the system comprising:

2   a representation module that represents a virtual object as a volumetric model;

3   a conversion module that converts a subset of the volumetric model into an alternative

4   representation;

5   an analytic module that determines a response of the alternative representation to a

6   stimulus; and

7   a modification module that modifies the volumetric representation so as to substantially

8   represent the response of the alternative representation to the stimulus.

1   29.   The system of claim 28, wherein the analytic module that determines a response of the

2 alternative representation to a stimulus comprises an analytic module that determines a response

3 of the alternative representation to a first stimulus and further determines a response of the

4 alternative representation to a second succeeding stimulus.

1   30.   The system of claim 28, wherein the modification module that modifies the volumetric

2   representation comprises a modification module that changes a shape of the volumetric

3   representation.

1   31.   The system of claim 28, wherein the modification module that modifies the volumetric

2   representation comprises a modification module that converts the response of the alternative

3   representation to the stimulus into a response of the volumetric representation to the stimulus.

32.   The system of claim 28, wherein the subset of the volumetric model is the entire

2   volumetric model.

1   33.   The system of claim 28, wherein the subset of the volumetric model is a portion of the

2   volumetric model.

1   34.   The system of claim 28, wherein the volumetric model comprises voxels.

1   35.   The system of claim 28, wherein the volumetric model comprises values spaced in a

2   three-dimensional grid.

1   36.   The system of claim 28, wherein the alternative representation comprises a surface

2   representation.

1   37.   The system of claim 28, wherein the alternative representation comprises a set-of-

2   triangles representation.

1   38.   The system of claim 37, wherein the stimulus comprises a weighted displacement

2   function defined on vertices of the set-of-triangles representation.

1 39. The system of claim 28, wherein the alternative representation comprises a selected one

2 of a polygon set, a bezier surface, a b-spline surface, a procedural surface, and a NURBS

3 representation.

1 40. The system of claim 28, wherein the alternative representation comprises an alternative

2 voxel representation.

1 41. The system of claim 28, wherein the stimulus is a stimulus from a user using a haptic

2 interface.

1 42. The system of claim 41, wherein the haptic interface is a force feedback interface.

1 43. The system of claim 41, wherein the haptic interface has at least three degrees of force

2 feedback.

44. The system of claim 28, further comprising a display module that displays the virtual

object on a computer display.

45. The system of claim 28, wherein the volumetric representation and the alternative

representation comprise representations having different numbers of dimensions.

1 46. The system of claim 28, wherein the applied stimulus comprises at least one of a

2 displacement function, a smoothing function, a warping function, a volumetric interference, an

3 areal interference, a result of a simulation, a control point modification, a data re-fitting, and a

4 force.

1 47. The system of claim 28, wherein the applied stimulus is applied to the object in real time.

1 48. The system of claim 28, further comprising:

2   a second transformation module that transforms the alternative representation into a third

3   representation;

4   a third modification module that modifies the third representation in response to an

5   applied stimulus; and

6   a third transformation module that transforms the modified third representation to a

7   modified volumetric representation.

1   49.   The system of claim 48, wherein the third transformation module that transforms the

2   modified third representation to the modified volumetric representation comprises a

3   transformation module that generates an intermediate modified representation.

1   50.   The system of claim 48, wherein at least two of the first, second and third modification

2   modules are the same module.

1   51.   The system of claim 48, wherein at least two of the first, second and third transformation

2   modules are the same module.

1   52.   The system of claim 28, wherein the stimulus comprises a user motion in the at least

2   three-dimensional space.

1   53.   The system of claim 28, further comprising a force feedback module that applies a

2   feedback force to a user, the feedback force being generally consistent with a geometric shape of

3   a modified virtual object.

1   54.   A system of modifying a volumetric representation of an object, the system comprising:

2   a transformation module that transforms at least a portion of the volumetric representation

3   into a polygonal set representation;

4   a first modification module that modifies the polygonal set representation; and

5   a second modification module that modifies the volumetric representation to substantially

6   represent the modification made to the polygonal set representation.

1   55.   The system of claim 54, wherein a selected one of the modification of the polygonal set

2   representation and the modification of the volumetric representation comprises a selected one of

3   a displacement function, a smoothing function, a warping function, a volumetric interference, an

4   areal interference, a result of a simulation, a control point modification, a data re-fitting, and a

5   force.

1   56.   A system of modifying a volumetric representation of an object, the system comprising:

2   a transformation module that transforms at least a portion of the volumetric representation

3   into a surface-based representation;

4   a first modification module that modifies the surface-based representation; and

5   a second modification module that modifies the volumetric representation to substantially

6   represent the modification made to the surface based representation.